From: Book, Steven (DHS)
Sent: Monday, February 02, 2004 12:07 PM
To: Hauge, Carl
Cc: Guivetchi, Kamyar; Andrew, John; Sumi, David; Yamamoto, Gary (DHS-DDWEM); Giannopoulos, James ; Juricich, Rich A.; Dabbs, Paul
Subject: FW: The latest morph

Some additions to Table 3, and a few minor editorial suggestions…

-----Original Message-----
From: Hauge, Carl
Sent: Monday, January 26, 2004 4:28 PM
To: Guivetchi, Kamyar; Andrew, John; Sumi, David; Gary Yamamoto; Steven Book; giannopj ; Juricich, Rich A.; Dabbs, Paul
Subject: The latest morph

If you can review this I would appreciate that effort. Thanks.

Carl Hauge, Chief Hydrogeologist, Department of Water Resources

Groundwater Remediation / Aquifer Remediation

Groundwater remediation is the terminology used to describe remediation of contaminated groundwater. Groundwater remediation involves extracting contaminated groundwater from the aquifer, treating it, discharging it to a water course, or using it for some agricultural or municipal purpose. It is also possible to re-inject the treated water back into the aquifer.

In the process of groundwater remediation, neither the aquifer nor the groundwater in the aquifer is being treated *in situ,* but the groundwater is flowing through the aquifer toward the extraction wells. If recharge of the aquifer continues, this flow provides a flushing action that may eventually remove most of the contaminants from the aquifer. This is also called the 'pump and treat' method of remediation. Pump and treat methods transfer the contaminant to another medium, either the atmosphere or a filter material. If a volatile material is transferred from the groundwater to the atmosphere, permits must be obtained from the appropriate air pollution control district or agency for the amount to be transferred. If a filtration medium is used, such as granular activated carbon (GAC), the GAC must be disposed of as a hazardous waste, or if the GAC is regenerated, the waste from that process must be disposed of as a hazardous waste. If the contaminant is radioactive, such as uranium, then residuals may need to be disposed of as radioactive waste.

Aquifer remediation is usually accomplished by treating the groundwater using *in situ* methods involving physical or chemical treatment, biological treatment, or electrokinetics (see Table 2).

Another term used for either of these remediation processes is 'groundwater restoration.'

Whatever the treatment method it must be suited to the chemical that has contaminated the aquifer. Light, non-aqueous phase liquids (LNAPLs), such as hydrocarbons, float on the surface of the groundwater. Dense, non-aqueous phase liquids (DNAPLs), such as trichloroethylene, TCE, have a specific gravity greater than water and sink to the bottom of the aquifer. Other contaminants such as MTBE may be miscible in water and are in solution in the groundwater. Even with LNAPLs and DNAPLs there is some dissolution of the contaminant within the groundwater in the aquifer.

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Current Groundwater Remediation and Groundwater/Drinking Water Treatment in California

Groundwater Remediation and Reuse

There are approximately 18,500 sites in the state where active cleanup of contaminants is ongoing. Regulatory oversight of these cleanups is by Regional Water Quality Control Boards (Regional Boards), the Department of Toxic Substances Control (DTSC) or local agencies. Of the approximately 18,500 sites, 15,000 are sites that have had a petroleum release from a leaking underground storage tank (UST) system. Most of the 18,500 sites have groundwater impacts. A petroleum release is detected by analyzing for total petroleum hydrocarbons (TPH).

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According to the Agency for Toxic Substances and Disease Registry (ATSDR), TPH is a term used to describe a large family of several hundred chemical compounds that originally come from crude oil. Crude oil is used to make petroleum products, which can contaminate the environment. Because there are so many different chemicals in crude oil and in other petroleum products, it is not practical to measure each one separately. However, it is useful to measure the total amount of TPH at a site.

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TPH is a mixture of chemicals, but they are all made mainly from hydrogen and carbon, called hydrocarbons. Scientists divide TPH into groups of petroleum hydrocarbons that act alike in soil or water. These groups are called petroleum hydrocarbon fractions. Each fraction contains many individual chemicals.

Some chemicals that may be found in TPH are hexane, jet fuels, mineral oils, benzene, toluene, xylenes, naphthalene, and fluorene, as well as other petroleum products and gasoline components. However, it is likely that samples of TPH will contain only some, or a mixture, of these chemicals. Some TPH fractions will float on the water and form surface films, while other TPH fractions will sink to the bottom sediments. Bacteria and microorganisms in the water may break down some of the TPH fractions, while some TPH fractions will move into the soil where they may stay for a long time.

(The previous 3 paragraphs are from the ATSDR's web page at: http://www.atsdr.cdc.gov/tfacts123.html)

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In general, cleanup for the vast majority of contaminant sites involves excavation, free-product removal if applicable, soil vapor extraction, in situ remediation, or a combination of these remediation methods. Pump and treat methodology tends to be expensive and is not employed when other effective remediation options are available. The discharge from a pump and treat system may also require a discharge permit issued by a Regional Board.

Except for responsible parties reimbursed by the Underground Storage Tank Cleanup Fund (Fund), it is difficult to estimate the cost of cleaning up contaminated sites. However, the Fund reimburses approximately $180 million annually to eligible claimants, and it is estimated that major oil companies that have not been reimbursed are expending between $50-$100 million annually on their sites. Therefore, costs associated with the cleanup of all UST sites in California appear to easily exceed $300 million annually. The cost to clean up an individual UST site typically ranges between $100,000 - $200,000. The cleanup of UST sites with MTBE is costing significantly more than the average, with reimbursements as high as the Fund limit of $1.5 million per site.

The cost of cleaning up non-UST sites is also highly variable. A site where solvent contamination has reached groundwater may require continuous pump and treat operation for decades and cost millions of dollars.

Groundwater Remediation

There are approximately 800 sites with pump and treat systems Approximately one third of these are at UST sites, where shallow groundwater is typically affected. The treated flow

volumes are on the order of 10-20 gallons per minute. At a small number of sites the volume treated can be millions of gallons per day.

Volatile organic compounds (VOCs) such as trichloroethyelene (TCE) and tetrachloroethylene (PCE) (see Table 1) are being removed from groundwater in Los Angeles, from the San Gabriel basin. VOCs are also being removed in Santa Clara County. Often these cleanups are associated with federal Superfund projects, e.g., the Glendale Operable Unit (OU), or the Burbank OU.

Table 1—List of Contaminants*
1,2-Dibromo-3-chloropropane, DBCP
1,2-Dichloroethane
1,2,3-Trichloropropane, 1,2,3-TCP
Arsenic, As
Carbon tetrachloride, CTC
Ethylene dibromide, EDB
Methyl tertiary butyl ether, MTBE
N-Nitrosodimethylamine, NDMA
Nitrate as NO_3
Nitrate + Nitrite as N
Perchlorate, ClO_4
Tetrachloroethylene, PCE
Total petroleum hydrocarbons, TPH e.g, hexane, jet fuels, mineral oils, benzene toluene, xylenes, naphthalene, fluorene
Trichloroethylene, TCE
Uranium, U
* Some may also be called by other names

Perchlorate is being removed by ion exchange and biological treatment in Sacramento and San Gabriel basins.

In Sacramento and Santa Clara, the treated water is released into a surface water channel, whereas in San Gabriel, the treated water is pumped into the public water supply distribution system.

Table 2—Types of Treatment
Pump and Treat
Activated alumina
Biological
Blending
Coagulation/filtration
Granular activated carbon, GAC
Ion exchange, IX
Lime softening
Packed tower aeration (air stripping)
Reverse osmosis, RO
Ultra-violet photoionization
In-situ
Air sparging
Bio-sparging
Bio-venting
Cosolvents
Electrokinetics
Electron acceptors (nitrate, sulfate, ferric ions)
Electron donors (to degrade chlorinated hydrocarbons)
Fluid cycling
Hydrofracturing/Pneumatic fracturing
Soil vapor extraction
Surfactant enhancements
Thermal enhancements
Treatment walls
Vitrification

Groundwater/Drinking Water Treatment

Besides the groundwater remediation projects mentioned above, there are drinking water treatment projects for VOCs, including TCE, PCE, that are operating in various water systems (see Table 3). The gasoline additive MTBE is being treated in the City of Santa Monica, and in several smaller systems.

Arsenic treatment is occurring in a few water systems to meet the current MCL of 50 micrograms per liter. In 2006, the new federal MCL of 10 micrograms per liter becomes effective, and it is predicted that additional water systems will be required to treat to remove arsenic systems.

Water systems are using ion exchange to treat perchlorate in several counties.

Pesticides, especially 1,2-dibromo-3-chloropropane (DBCP) and ethylene dibromide (EDB), are being removed in the San Joaquin Valley and southern California.

Nitrates in groundwater are being blended or treated in most areas of the state where agriculture has been active, either in the past or today, and wherever there are high concentrations of septic tank treatment and disposal systems.

TABLE 3--LOCATIONS OF GROUNDWATER SOURCES OF DRINKING WATER WITH SELECTED DETECTED CONTAMINANTS

Information provided by California Department of Health Services, Division of Drinking Water and Environmental Management

Contaminant	**Counties Affected (# of sources with detections)***	**Types of Treatment Used**	**Examples: Water Systems to Contact for Additional Information**
	REGULATED CONTAMINANTS		
Inorganic Chemicals			
Arsenic (current MCL – 50 ppb, **	Kern (10), Kings (13), San Bernardino (7), Sonoma (6), Nevada (5), Sutter (5), Los Angeles (4), Mono (4)	activated alumina; ion exchange (IX), reverse osmosis (RO), (others with limitations—see 22 CCR § 64447.2), blending	Edgemont Acres MWD; Boron CSD; Mt. Weske Estates MWC; City of Signal Hill
Arsenic (federal MCL, effective 2006 = 10 ppb)**	Kern (115), San Bernardino (70), Los Angeles (58), San Joaquin (56), Kings (37), Sacramento (37), Sutter (29), Sonoma (24), Riverside (20), Madera (15), Monterey (14), Fresno (13), Nevada (12), Tulare (12), Merced (10), Mono (9), Stanislaus (9), Napa (8)		
Nitrate as NO3	Los Angeles (171), San Bernardino (108), Riverside (79), Kern (64) Monterey (48), Fresno, Orange	IX, RO, blending	McFarland MWC, City of Pomona; Southern California Water Company; San Gabriel County Water District; CWS-Salinas; City of Fresno; Bakman Water Company; City of Garden Grove; City of Tustin
Nitrate + Nitrite as N	Los Angeles (80), San Bernardino (58), Riverside (31), Tulare (17), Ventura (13)		
Radioactivity			
Uranium	San Bernardino (46), Kern (38), Stanislaus (28), Riverside (28), Madera (20), Los Angeles (19); Monterey	IX, RO, lime softening, coagulation/ filtration	Cal Water, Lakeland; CWS-Salinas
Volatile Organic Chemicals			
Carbon tetrachloride	Los Angeles (95)	granular activated carbon (GAC), packed tower aeration, blending***	San Gabriel Valley Water Company; City of Monterey Park; La Puente Valley CWD
1,2-Dichloroethane	Los Angeles (90), El Dorado (10)		Southern California Water Company; La Puente Valley CWD
Methyl tertiary butyl ether (MTBE)	Los Angeles (6), Kern (5), Monterey, San Mateo, Madera		City of Santa Monica; Cal-Am WC – Montara; Riverview WD; CWS-Salinas; Yosemite Spring Park Utility Company

Tetrachloroethylene (PCE)	Los Angeles (152), San Bernardino (27), Sacramento (8), Kern (6), Fresno (5), Monterey		City of Burbank; San Gabriel Valley Water Company; City of Monterey Part; EPA-Whittier Narrows OU; City of Whittier; Southern California Water Company CWD-Salinas; La Puente Valley CWD
Trichloroethylene (TCE)	Los Angeles (196), Fresno (17), Riverside (14), San Bernardino (10), Butte		City of Burbank; City of Glendale; Cal Water Service Co, Chico; La Puente Valley CWD
Pesticides			
1,2-Dibromo-3-chloropropane (DBCP)	Fresno (121), San Joaquin (35), Tulare (35), San Bernardino (34), Madera	blending, GAC	City of Fresno; City of Clovis; City of Sanger; CalWater, Visalia; City of Lodi; City of Madera
Ethylene dibromide (EDB)	Fresno (15), Kern (11), San Joaquin (5), Madera	blending, GAC, packed tower aeration	City of Fresno; City of Madera
UNREGULATED CONTAMINANTS (No MCL)			
Inorganic chemical			
Perchlorate (MCL to be established—see DHS website for status)	Los Angeles (134), San Bernardino (80), Riverside (61), Orange (31), Sacramento (13), Tulare (8), Santa Clara (7)	IX, biological, blending	California Domestic WC; La Puente Valley CWD; City of Redlands; San Gabriel Valley WC-Fontana; City of Riverside; City of Colton; City of Rialto; So Cal Water Co., So San Gabriel; City of Morgan Hill
Semivolatile Organic Chemical			
N-Nitrosodimethylamine (NDMA)	Los Angeles (~5)	UV photoionization	San Gabriel Valley Water Company; City of Industry; La Puente Valley CWD
Volatile Organic Chemical/Pesticide			
1,2,3-Trichloropropane (1,2,3-TCP)	Kern (75), Los Angeles (29), Fresno (23), Tulare (18), San Bernardino (16), Merced (13); Riverside (7), San Joaquin (7), San Diego (6), San Mateo (5), Stanislaus (5)	see VOCs above	City of Burbank

* The numbers of sources are from the DHS database, including analyses reported 1994-2002 (see http://www.dhs.ca.gov/ps/ddwem/chemicals/monitoring/results94-02.htm except for MTBE, perchlorate, and 1,2,3-TCP, which are through 2003 http://www.dhs.ca.gov/ps/ddwem/chemicals/chemindex.htm. Arsenic data are from 2000-2002 http://www.dhs.ca.gov/ps/ddwem/chemicals/arsenic/newmcl.htm, and the NDMA estimate is from the narrative at http://www.dhs.ca.gov/ps/ddwem/chemicals/NDMA/history.htm. For "Regulated Contaminants" the number in parenthesis represents detections greater than MCLs. For "Unregulated Contaminants of Interest" the number represents overall detections. **In general, counties with only a few detections are not included, unless an example of a water system providing treatment is provided in a particular county.** For more information on drinking water treatment technologies, contact the local DHS drinking water office (see the DHS website for office locations), or contact specific water systems that are addressing a contaminant problem.

**Arsenic currently has an MCL of 50 ppb. In 2006, compliance with a new federal MCL of 10 ppb is required. This will increase the number of sources will detections greater than the MCL from a total of about 80 to over 600.

***some systems are or may be considering use of advance oxidation processes, such as ultraviolet, or ozone for VOC treatment.

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Potential Benefits from Remediation of Groundwater (not associated with treatment of a drinking water source)

The potential benefits of remediating contaminated groundwater so the water can be used as a part of the available water supply are:

- An additional water supply is available that would not be available without remediation
- The cost of buying an alternative water supply is avoided
- Eventually, through the flushing action, the aquifer may be cleaned up to the point that treatment is no longer required

Potential Costs

With Remediation of Groundwater

The cost of remediating groundwater includes:

- Cost of characterizing the groundwater or aquifer, in terms of all the contaminants present
- Capital cost of the system, whether groundwater or aquifer remediation
- Operation and maintenance costs during the life of the project
- Remediation may be required for a long time

Without Remediation of Groundwater

Potential costs if groundwater is not remediated include:

- Cost of an alternative water supply
- Long-term foregone profits and taxes from businesses and activities that did not locate in the basin because of water shortages
- No opportunity for development of residential areas because there is no water supply available
- Contaminant may spread further, requiring greater and more costly remediation in the future

Major Issues Relating to Remediation of Groundwater

Water Quality—

- The type of constituent and the concentration of the constituent varies from aquifer to aquifer
- Contaminated water, particularly that which is associated with a hazardous waste facility or a Superfund site, may contain a variety of regulated and unregulated contaminants,
- Contaminated water may be poorly characterized, in terms of the contaminants that are present.
- Locating the dimension of the plume is costly
- These data are required before a remediation program can be designed

- Potential for other contaminants being detected subsequently that could cause the need for additional treatment facilities
- The sources of the contamination need to be found and eliminated (or the amount of discharge reduced), so that the groundwater basin can be cleaned up

Water Quantity--

- Aquifer geometry and characteristics must be known
- A water budget should be developed

Local Government and Land Use—Local government and local agencies should

- Limit potentially contaminating activities in areas where recharge takes place
- Work together to develop a sustainable good quality long-term water supply for beneficial uses

Costs of Treatment

- Who will pay, who are the responsible parties?
  - what is the appropriate share for each responsible party?

Potential Impacts

- Groundwater remediation will increase the available water supply
- Aquifer remediation will increase the amount of storage capacity that is available for use without treatment

Recommendations to help promote remediation of groundwater

1. Provide additional funding where appropriate to help local agencies and governments develop remediation projects.

2. Identify the agencies or entities that caused the contamination more quickly, so that they can provide funding to build treatment facilities and operate and maintain them.

3. Provide technical assistance for remediation projects.

4. Compile information on currently operating remediation projects, including:

   a. contaminant or contaminants involved
   b. amount of contaminant(s) in the aquifer that must be removed, which will require many more monitoring wells
   c. type of treatment
   d. expected length of operation of the treatment project, which is directly dependent on the data collected under part (b) above
   e. capital cost of the project

f. annual operating and maintenance cost, including costs of waste disposal
g. amount of groundwater treated per unit time
h. Seasonality of volume treated (the amount may vary seasonally depending on usage)
i. number of wells extracting groundwater
j. number of connections served

5. Local governments and local agencies should implement source water protection measures based on the source water assessments that were completed as of 2003 to protect recharge areas from contamination, so that groundwater remediation will not be necessary in the future.

Acknowledgments

Information for this write-up was provided by California Department of Health Services, Division of Drinking Water and Environmental Management; and by California State Water Resources Control Board, Division of Clean Water Programs.

Information sources

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